12th International Conference on CFD in Oil & Gas, Metallurgical and Process Industries
SINTEF, Trondheim, Norway
May 30 – June 1, 2017
ABSTRACT NO. (Will be filled in by organizer)

Can Large-Eddy Simulations Correctly Predict a Turbulent Stenotic Flow in a Patient-Specific Common Carotid Artery?

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Keywords: Stenosis, CFD, LES, Turbulence, DNS

ABSTRACT

Atherosclerosis is a leading cause of death in the westernized societies and the primary cause of stroke. Atherosclerotic plaques can grow into the arterial lumen sufficiently to obstruct the blood flow. The local narrowing of the lumen, known as stenosis, leads to the occurrence of flow phenomena such as separation, recirculation and instabilities in the downstream region.

Previous efforts to accurately characterize stenotic flow in patient-specific geometries have been performed with spectral elements method, direct numerical methods (DNS), and large-eddy simulations (LES). From a pragmatic point of view, LES is the most attractive method because of the reduced computational costs, however the validity of applying LES to a stenotic flow have not yet been tested.

All simulations were performed using our open-source CFD-solver *Oasis*, where special care has been taken to ensure a kinetic energy preserving and minimally dissipative numerical solution. The geometry was obtained through segmentation of pre-operative CT angiography images[1] of a severe constriction (82% by area) located in the internal carotid artery (ICA). Meshes were created using *Vascular Modelling Tool Kit*, simulations were performed on Abel supercomputer cluster, and inlet flow rate at peak systole (Re=1400) as well as ICA:ECA flow ratio (32:68) were set to mimic physiological values[2].

A DNS approach was used to create a *gold standard in silico* reference solution. First, a spatial refinement study was performed ranging from 2 to 50 million (M) linear tetrahedral cells, followed by a temporal refinement study with Δt ranging from 5e-4 to 5e-6 seconds.

The second phase of the study involved the comparison of the LES and DNS (reference solution) using both constant (peak systole) and pulsatile inlet flow. This was performed for Reynolds numbers ranging from 550 to 1100 as the mean flowrate in the pulsatile inlet flow.

Since future work will focus on validation of numerical model against data from *in vitro* experiments, we will compute the sensitivity with respect to flow split, and noise in the inflow pulse in the *in silico* experiments which can vary in the *in vitro* experiments.

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SAMPLE RESULTS

Preliminary results on the coarsest mesh show (Figure 1) that the most intense velocity fluctuations (1), can be found at 2 to 3 diameters downstream of the stenosis as the flow diverges and decelerates, as expected, and the re-laminarization occurs already at 5D. To assess how well resolved the meshes were we computed l+, which compares the length scale of the mesh with the Kolmogorov scales, and compared the power spectral density of different probe locations.

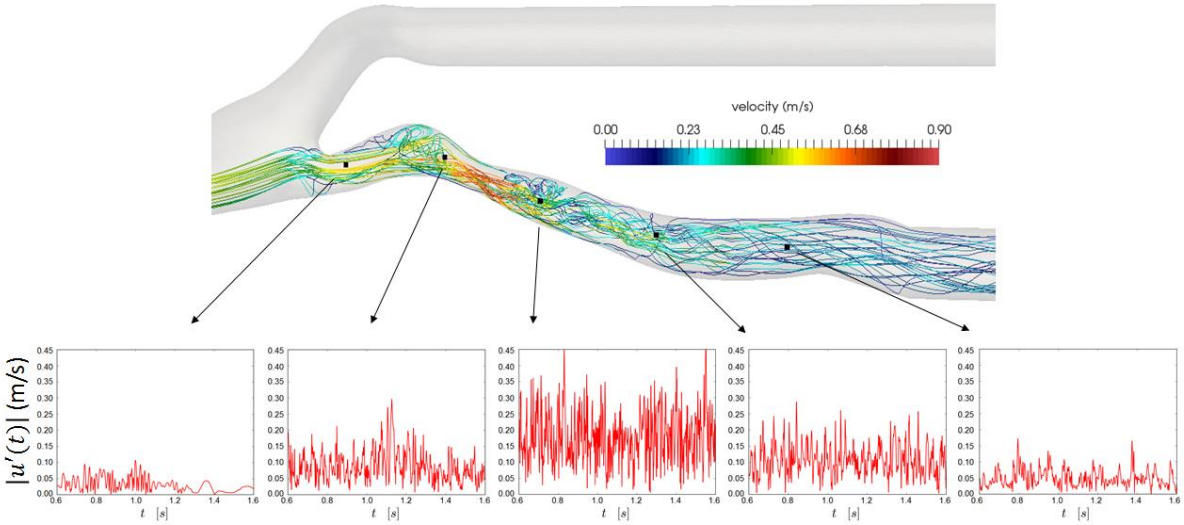

Figure 1: Streamlines in the internal carotid artery (upper row) and magnitude of fluctuating velocity in each probe location (bottom row).

$$|u'(t)| = \sqrt{\left[u(t) - \overline{u(t)}\right]^2} \tag{1}$$